

E-waste projection using life-span and population statistics

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Abstract

Purpose E-waste is the most rapidly growing problem throughout the world, which has serious future concerns over its management and recycling. This article proposes a simple approach for future e-waste projection which can be obtained by using life-span data of various electronic items along with incorporation of population statistics.

Methods For this purpose, 7-year sales data of electronic items were collected, which is then used to generate various

mathematical equations. These mathematical relations are then modified by incorporating life-span and population data.

Results and discussion By comparing sales data with their life-span (average) and population statistics, future e-waste can be quantified both in terms of specified area under investigation and proposed estimation area. The following equation is thus proposed:

$$\text{E-waste (In terms of quantity)} = [m\{\text{Waste projection year} - \text{Life-span}\} - \text{Initial data collection year} + C] \times \frac{\text{Population of estimation area}}{\text{Population of study area}}$$

Where m and C can be obtained from plotting year-wise sales data over Excel sheet.

Conclusions Local as well as global projection of future e-waste can be possible with the help of final equation.

Keywords E-waste · Life-span data · Mathematical modeling · Population statistics · Projection

1 Introduction

Increasing quantity of e-waste is the most rapidly growing problem throughout the world, which has serious future concerns over its management and recycling (Pinto 2008;

Wath et al. 2011; Pant et al. 2012; Jha et al. 2011). E-waste is a combination of both electronic and electrical waste. Generally, it corresponds to the various end-of-life products, such as television, computers, laptops, mobile phones, refrigerators, washing machine, and MP3 players, which have been already discarded by their owners.

Developing countries face much bigger problem from e-waste due to various reasons like: (1) technological upgradation either from advancement or import, (2) increased production of electronic products year after year and, (3) developed countries continuously dump their e-waste to these countries (Leung et al. 2006). Hence, e-waste management in the developing countries, like India, is an urgent need of the hour. The number of electronic products produced globally and locally is continuously increasing day by day, out of which a huge amount of these items becomes obsolete whose proper management is a major concern (Wath et al. 2011; Jha et al. 2011; Zhang et al. 2011).

Life-span or life expectancy is a time length for a product when either it may get repaired economically or spare parts may be available (Solomon et al. 2000). Life cycle of electronic products begins from the time of its manufacture

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till it gets disposed off by the user. Life-span of some electronic appliances is as follows: refrigerator (3–6 years), microwave (3–6 years), washing machine (3–6 years), desktop (8–10 years), laptop (3–5 years), AC (10–15 years), and TV (13–26 years). Here, it is important to note that the life expectancy of different items can also vary depending upon the way to handle by the owner (Retra 2011). A review of the above literature reveals that e-waste production is depending upon sale and life-span of the product and population of the area; hence, it is reasonable to incorporate these data for studying future e-waste projection. The current paper proposes a mathematical model for the projection of electronic waste items by using a combination of sale, life-span, and population data, for efficient e-waste management strategy.

2 Study methodology

Dehradun City, the capital of Uttarakhand, one of the northern states of India, is selected as a model for the present study. This district had a population of 791,000 in the year 2010 with diversified economic classes of society (Dehradun Master Plan 2025 2012). Year-wise population data were collected from the official website of district municipal board <http://www.mddaonline.com>. The average life-span of some electronic appliances taken for this study is as follows: refrigerator (4.5 years), microwave (4.5 years), washing machine (4.5 years), desktop (9 years), laptop (4 years), AC (12.5 years), and TV (19.5 years).

2.1 Data collection

For this purpose, electronic sales data of different electronic and consumer goods companies were collected from their

distributors in the form of raw data with two focus questions:

- Year-wise sell of particular electronic item (in number) and
- Growth rate of company

Selection of particular electronic item depends upon the availability of the common data. The electronic items selected for this study were TV, washing machine, refrigerator, microwave, AC, desktop, and laptop. The data thus obtained from the survey were plotted over an Excel worksheet (Windows 7), and resultant straight line equation is then compared with their respective life-span and existing population data for e-waste projection equation.

3 Results and discussion

3.1 Population and sale

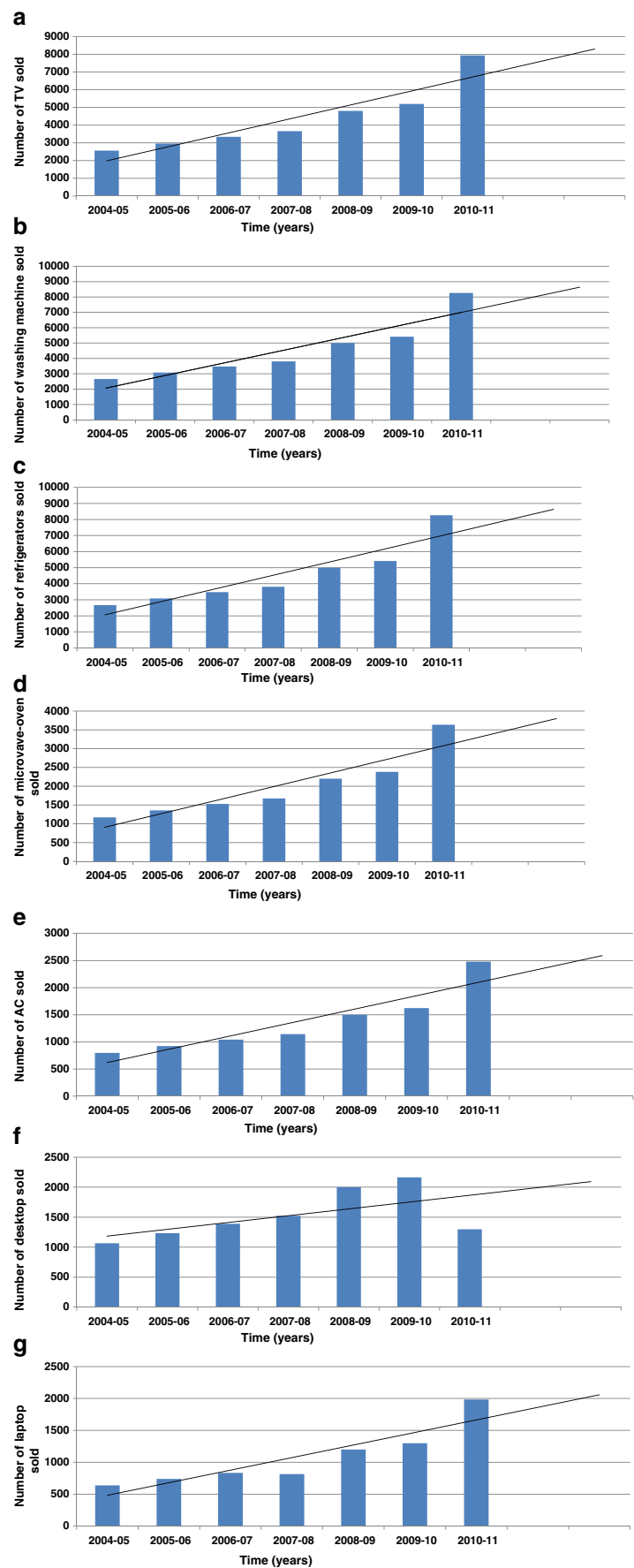
Table 1 represents the year-wise sales of different electronic goods and respective population data. A perusal of this table reveals that starting from 2004: (1) sale of all electronic items increases with diversified ranges in between 9–53% annually; (2) population increases gradually at a rate of 4% per year except for 2009, where it is declined by 0.5%, and (3) from year 2004 to 2011, the population was grown nearly half times whereas the number of sale of electronic item was increased approximately to twice. So, with respect to population growth, the number of electronic goods sold per year increased rapidly, which is quite reasonable due to technological upgradation (either from advancement or import) along with variation in life-span of electronic products (Retra 2011). Therefore, it can be concluded that the population and sales of any electronic goods are related to each other.

Table 1 Year-wise sales of electronic goods in Dehradun City with population data

Financial year	Electronic items (in numbers)							Population in the respective year ^a
	TV	Washing machine	Refrigerators	Microwave oven	AC	Desktop	Laptops	
2004–2005	2,556	2,662	2,662	1,171	798	1,065	639	630,917
2005–2006	2,958	3,081	3,081	1,356	924	1,233	740	656,154
2006–2007	3,336	3,475	3,475	1,529	1,042	1,390	834	682,400
2007–2008	3,657	3,809	3,809	1,676	1,143	1,524	914	708,200
2008–2009	4,800	5,000	5,000	2,200	1,500	2,000	1,200	734,100
2009–2010	5,196	5,412	5,412	2,381	1,624	2,165	1,299	760,000
2010–2011	7,933	8,263	8,263	3,636	2,479	1,299	1,983	791,000

^a Respective year represents the starting year of the financial year

Fig. 1 Year-wise sales data for:
a TV; **b** washing machine; **c** refrigerators; **d** microwave oven; **e** AC; **f** desktop; and **g** laptops



3.2 Projection of sales data with life-span and quantification of future e-waste

A perusal of Fig. 1 depicts year-wise sales of various electronic goods, by which (except desktop, with growth retardation from 2009) a positive sales growth in the various electronic goods during the period of 2004 to 2011 is quite evident.

3.2.1 Straight line equation

Straight line equation $y=mx+c$ was obtained from year-wise sales data (see Fig. 1 and Table 2), where y represents numbers of any particular electronic item sold in the

particular year and x stands for year of data collection. Trend line on each of these curves can provides information regarding the future sale of the respective item.

3.2.2 Life cycle modification for waste projection

Life cycle or span can provide an approximate relationship of any consumer item towards resultant waste. The number of projected e-waste with particular electronic item (in terms of the number of annual refuse) can be obtained by associating the sale of particular electronic goods with their life cycle. For this purpose, x from the straight line equation can be modified as (see Table 2):

$$x = [\{\text{Waste projection year} - \text{Life-span}\} - \text{Initial data collection year for the item}]$$

3.2.3 Population statistical modification

With increasing population, e-waste has also been increasing and population statistics is an approach to correlate waste data with population. For the population statistical modification, population of the estimation area and study area is required for the same year. The following factor is therefore associated for incorporating

population statistical modification in waste projection equation (see Table 2):

Population statistical modification

$$= \frac{\text{Population of estimation area}}{\text{Population of study area (where data are to be collected)}}$$

Table 2 Life cycle and population statistical modification equations for e-waste projection

Name of the electronic item	Straight line equation	Life cycle modification for waste projection	Population statistical modification
TV	$y=788.3x+1,194$	$n_{tv}=788.3 [(a^a-19.5^b)-2004^c]+1,194$	$N_{TV}=[788.3 \{(a-19.5)-2004\}+1,194] \times \text{Population of estimation area/Population of Dehradun}$
Washing machine	$y=821.0x+1,244$	$n_{wm}=821 [(a-4.5^b)-2004]+1,244$	$N_{WM}=[821 \{(a-4.5)-2004\}+1,244] \times \text{Population of estimation area/Population of Dehradun}$
Refrigerator	$y=821.0x+1,244$	$n_r=811 [(a-4.5^b)-2004]+1,244$	$N_R=[811 \{(a-4.5)-2004\}+1,244] \times \text{Population of estimation area/Population of Dehradun}$
Microwave oven	$y=361.2x+547.5$	$n_{mo}=361.2 [(a-4.5^b)-2004]+547.5$	$N_{MO}=[361.2 \{(a-4.5)-2004\}+547.5] \times \text{Population of estimation area/Population of Dehradun}$
AC	$y=246.4x+372.7$	$n_{ac}=246.4 [(a-12.5^b)-2004]+372.7$	$N_{AC}=[246.4 \{(a-12.5)-2004\}+372.7] \times \text{Population of estimation area/Population of Dehradun}$
Laptops	$y=197x+299$	$n_l=197 [(a-4^b)-2004]+299$	$N_L=[197 \{(a-4)-2004\}+299] \times \text{Population of estimation area/Population of Dehradun}$
Desktop	$y=331.4x+473.4$	$n_d=331.4 [(a-9^b)-2004]+473.4$	$N_D=[331.4 \{(a-9)-2004\}+473.4] \times \text{Population of estimation area/Population of Dehradun}$

Where n and N refer to waste items generated for the specified area under investigation and estimation (proposed), respectively

^a Waste projection year

^b Average life-span values (in years)

^c Initial data collection year

By comparing these data with their existing life-span (average) and population statistics, future e-waste can be quantified both in terms of specified

area under investigation and proposed estimation area (see Table 2). The following equation is thus proposed:

$$\text{E-waste (In terms of quantity)} = [m\{\text{Waste projection year}-\text{Life-span}\}-\text{Initial data collection year} + C] \times \frac{\text{Population of estimation area}}{\text{Population of study area}}$$

Where m and C can be obtained from plotting year-wise sales data over Excel sheet

Further research is needed for applying this equation in the form of software for future e-waste approximation.

4 Conclusions

Long-term planning is required for effective and affordable e-waste management. This study provides a mathematical equation for the predication of e-waste from a particular electronic item by incorporating sale of the item, life-span, and population statistic. The equation thus projected for e-waste estimation can be applied for the future waste projection in local or global level. On the basis of the present study, it can be inferred that:

1. From the proposed equation, it is possible to generate e-waste data for any country or the whole world by utilizing sales data from any model city as a primary unit;
2. Population statistic (comparison of the population of the waste estimating area with the study area) is an important parameter for e-waste projection;
3. The result of the survey reveals a positive growth in sales rate for all electronic items with moderate variation.
4. This relation is an easy approach for the estimation of e-waste for its planning strategy.

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